

of Pascal, that when a liquid is put into a closed vessel, and then subjected at any point to a pressure, this pressure is transmitted equally in all directions. If the vessel be a strong one and provided with two movable pistons, a large and a small one, the area of the large piston being many times as great as that of the small one, any pressure exerted upon the small piston to the liquid will be transmitted equally over equal amounts of surface, and hence the total pressure on the large piston will be many times as great as the original force, just in proportion as its area is greater than that of the small piston. This is, in fact, the principle applied in the hydraulic press of Bramah and in the hydraulic machinery of Sir W. Armstrong, by which heavy bridges, dock-gates, and elevators are set in motion. The writer of this article, when sore-pressed to devise an experimental illustration of the principle of the hydraulic press, contrived the following arrangement. The lid of a coffee-pot was removed and a piece of sheet-indiarubber was tied tightly over the open top. Into the spout a piece of lead-pipe about six feet long was inserted, firmly fixed with sealing-wax, and then turned up vertically. The pot was filled with water, and a heavy book placed upon the top. Water was poured into the lead tube until it was filled up to the top. A column of water six feet high affords a pressure of nearly three pounds per square inch, and this, exerted over the whole area of the rubber-covered top, gave a sufficient total pressure to raise the heavy book.

The air also possesses weight, and exerts a pressure which may be upwards or downwards according to circumstances. Let a wine-glass or a tumbler be filled full of water and a thin card laid upon the top of it, so that bubbles of air are excluded. Now invert the whole, pressing the card lightly on to the glass during the operation, to prevent accidents, and it will be found (see Fig. 9) that the water will remain in the wine-glass, and will not fall out. In fact the pressure of the air upwards against the card is much more than sufficient to counterbalance the downward pressure of the water in the wine-glass.

Most of the experiments upon the pressure of the air require, however, the aid of an air-pump for their performance. With the air-pump a large variety of interesting properties of the air can be demonstrated, which otherwise cannot be shown. A few, however, do not require the aid of this instrument. The effect of the external pressure of the air in raising the level of a liquid in a tube from which the air has been partially exhausted, thereby reducing its pressure, can be shown by sucking with the mouth at the top of a glass tube, the lower end of which dips into the liquid in question. Thus it is possible to suck up mercury to a height of fifteen inches into a tube; for the lungs are strong enough to reduce the air in the tube to about half the ordinary pressure. If a glass tube of sufficient length were available it would be possible to suck up water in it to a height of about sixteen or seventeen feet; for a column of that height would be sufficient to counterbalance the difference between the inside and outside pressures.

The rising of a liquid into a space from which the air has been partially removed may also be illustrated in the following pretty way. Take a small bit of card and let it float upon the surface of water in a shallow dish. Upon it place a few shavings of wood and light them with a match; or place a small red-hot coal upon it, and on this sprinkle a little brimstone to burn. Then quickly invert over the blazing mass a wine-glass or a tumbler, as in Fig. 10. As the shavings or the brimstone, as the case may be, burn away, they withdraw the oxygen of the air inclosed in the space above, until only the nitrogen (about four-fifths of the whole) remains. The gases inside, therefore, will not exert so great a pressure as before, and consequently the pressure of the air outside will

force the water to rise in the glass as the remaining gases cool down to the temperature at which they were at first.

(To be continued.)

ON THE ABSORPTION BANDS IN CERTAIN COLOURLESS LIQUIDS

[PRELIMINARY NOTICE]

HAVING occasion to examine the absorption spectra produced by considerable thicknesses of alcoholic solutions of certain cobalt salts, we were led accidentally to observe that alcohol alone gave a very distinct band, and afterwards, on examining water, found that it also, when a column of six feet was used, gave a very distinct absorption band in the orange, a little on the less refrangible side of D. By graphical interpolation we find the centre of this band to be about 600, and that the band extends from 607 to 596. This position corresponds very closely, if it be not identical, with Piazzi Smyth's rair band,¹ and also with the band seen in 330 feet of high-pressure steam by Janssen.²

Fig. 1 represents this spectrum. It will be seen that the absorption at the red end extends up to the line C, and the end of the shadow is so sharp that it is probable there is a band at this point also, but masked by the general absorption. To convince ourselves that this band belonged to water and not to any accidental impurity, we experimented with different samples of water, using ordinary tap-water, ordinary distilled water, also water which had been made with much care absolutely pure; in all these samples this same band was visible, and as long as the water was clear, as far as we could judge, it was of the same degree of intensity. A column of water eight feet long shows the band clearer than one only six feet; still greater lengths we have not yet tried. We next tried the effect of increase of temperature on the water. For this purpose the glass tube containing the water was fitted into an air-bath, and the temperature was raised from 20° to 60° without removing the tube from before the spectroscope; no change in the band, either in position or intensity, as far as we could see, occurred. Further, it seemed to us that it would be interesting to try whether, on dissolving different colourless substances in water, the band would be affected. We consequently examined saturated solutions of the following substances in a tube 8 feet long:—Ammonium chloride, ammonium nitrate, ammonium carbonate, potassium nitrate, lead nitrate, sodium chloride, and sugar. In all these cases the band was as visible as in pure water, and no additional band was seen. With a mixture of 1 volume of sulphuric acid and 5 of water the band was unaffected, but if pure commercial hydrochloric acid was examined in a 6-feet tube the band was invisible, but with 8 feet a faint indication of it was seen.

This absorption with water being so marked, we naturally went on to try whether other so-called colourless liquids gave, when depths of 6 or 8 feet of them were examined, absorption bands, and at first really our difficulty was to find any liquid which did not show clearly one or more bands.

The ordinary solution of ammonia gave a very clear and marked spectrum (Fig. 2). It consists of four bands, the centres of which are at 650, 630, 610, and 556. The band at 650 is much the darkest, and the band at 630 is remarkably sharp. Then with regard to the 610 band, it is characterised by sharpness only on the least refrangible side, but shades off gradually on the other side, the shade extending as far as 596; this shade is probably due to the water band; and lastly, the band at 556 is by far the

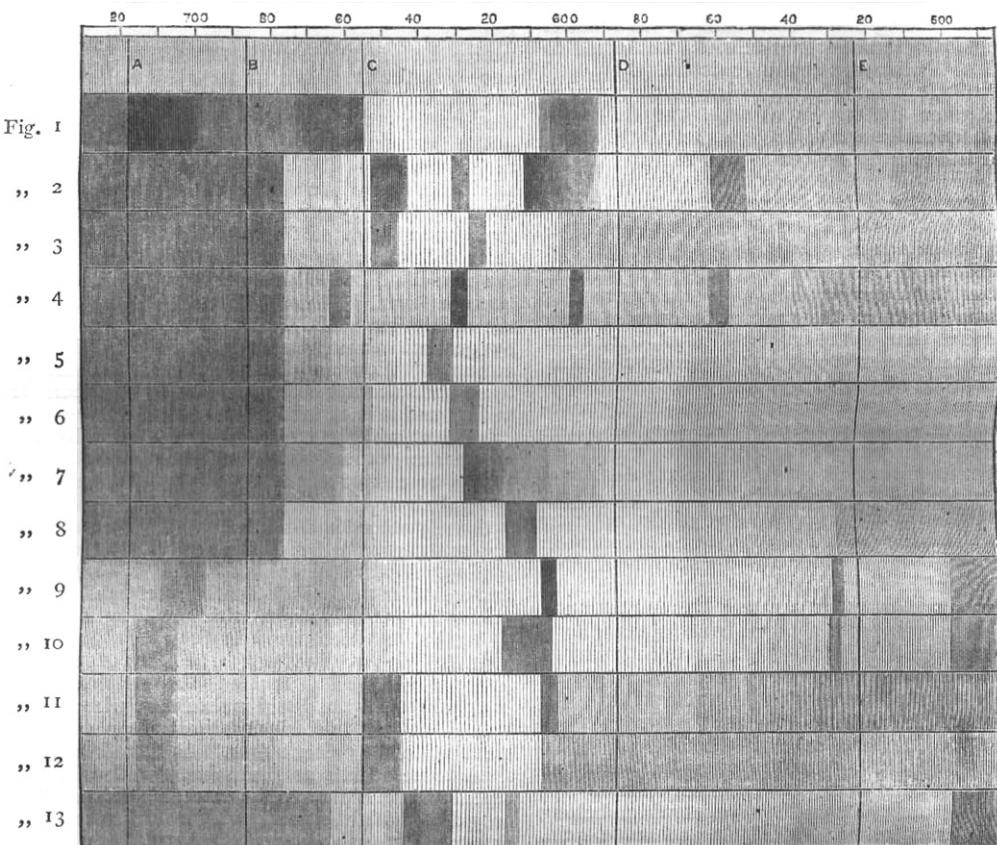
¹ Piazzi Smyth, "Edinburgh Astronomical Observations," vol. xiv.

² In this and the following experiments a Desaga's spectroscope with a single heavy glass prism was used, and the source of light was an Argand gas-burner. The measurements are expressed in the millionths of a metre.

faintest, and is only visible in a column of 8 feet. With the exception of the 556 band, the other bands are so distinct that in a nearly saturated solution 4½ feet in depth, they are clearly seen. This spectrum was so marked and intense that at first we were sceptical with regard to its belonging really to ammonia, thinking that possibly some coal-tar product might be still clinging to the commercial ammonia solution which in the first instance we used. To satisfy ourselves that this was not the case, first we added lime, and distilled the ammonia gas into pure water; this acted in exactly the same way as the former solution; then we obtained from Messrs. Hopkins and Williams what they guaranteed to be volcanic ammonia. A solution of this gave exactly the same spectrum as the former solutions. And lastly we prepared pure ammonia by Stas' method, by the action of caustic potash and zinc—free from

carbon—on potassic nitrite; this also gave precisely the same bands as the other ammonia solutions; there could therefore be no doubt that this spectrum belonged to the ammonia solution. Thirty-six feet of ammonia gas did not give us any indication of bands. Obviously this is only a mere trace of gas as compared with the amount held in the solutions before examined. To have as gas the same amount as there was of solution in our 6-feet tube, we should require a tube nearly a mile long. If absolute alcohol instead of water be saturated with ammonia, a spectrum (Fig. 3) still sharper than that with water is obtained, but similar to it, excepting that the band at 610 is wanting and the two bands at 650 and 630 now are of equal intensity, instead of the 650 band being decidedly and constantly the darker of the two. Ammonia giving so definite a spectrum it was evidently

Fig. I



1, Water; 2, Ammonia; 3, Ammonia in Alcohol; 4, Ethylamine; 5, Amyl Alcohol; 6, Ethyl Alcohol; 7, Aldehyde; 8, Acetic Acid; 9, Benzene; 10, Toluene; 11, Aniline; 12, Toluidine; 13, Turpentine.

of much interest to ascertain what spectra would be given by bodies of allied chemical constitution. Ethylamine was the next substance we tried. Using a 33 per cent. solution, this gave a spectrum (Fig. 4) similar in character to that of ammonia, but the dominant band, as far as we could ascertain, has clearly moved towards the red. It was now at 665 to 656. The next band is also somewhat nearer the red than the corresponding ammonia band. The position of the third band is very nearly identical with that of the water-band, but instead of being a wide band shading off on both sides, is now narrow and perfectly sharp. It will be noticed that in the alcoholic ammonia solution it is this band and the next more refrangible one that are absent.

For lack of material we have not yet examined the spectra of other organic ammonias, but intend doing so.

A solution of peroxide of hydrogen was also examined, using the commercial 20-volume solution. The liquid was not absolutely free from colour, and consequently there was a very appreciable amount of absorption over the whole spectrum. The water band was not visible, and in fact no sharp band could be seen; there was however a decidedly marked absorption commencing about 674, then the absorption is both dark and sharp; it extends, diminishing gradually, to 638; very probably this absorption may prove to be a band, but the experiment was not altogether satisfactory.

We naturally returned to alcohol and other typical organic liquids. Alcohol gives in the six-feet tube a very visible and fairly-defined band, more sharply defined than the water band and nearer the red. It extends from 632 to 624. The spectrum is given in Fig. 6. It will be

seen that a faint absorption extends as far as 650, and very likely the termination of this shade is a band. Fig. 6 represents the spectrum of a sample of pure absolute alcohol. Ordinary methylated spirit gives a very similar spectrum, differing only in the presence of some general absorption, and with a mixture of equal parts of methylated spirit and water the alcohol band was still clearly visible, and only a faint indication of the water band.

On referring now to the alcoholic solution of ammonia (Fig. 3), it will be seen that the probable explanation of the darkening of the 630 band is owing to the coincidence of the alcohol band with that of the ammonia, so that really the marked difference of the two ammonia spectra is in the absence of the 610 band, and this, we have seen, may be accounted for by one being an aqueous and the other an alcoholic solution.

Ethylic alcohol giving this definite band, it was a matter of much interest to examine other alcohols belonging to the same series. We found that amylic alcohol ($C_5H_{11}HO$) gave a single visible band (Fig. 5), which in character is like the one given by ethylic alcohol, but differs in position; it extends from 638 to 630, the centre being 634, so that it is decidedly nearer to the red end of the spectrum.

A sample of amylene (C_6H_{12}) gave also a band in the same position as that of the alcohol, but it differs apparently in being broader and less defined at the edges.

The sample of methylic alcohol was not quite pure nor free from colour, but it gave a band quite similar to that of the other two alcohols. Its position is certainly very nearly the same as that of the ethylic alcohol, but as far as our measurements went it was a little nearer the blue, but with our method of measuring hardly discernible.

It seems—pending further investigations—highly probable that this band—and of course there may be others not visible—is common to all the alcohols of the ethylic series, and that its position is a function of the density of the particular alcohol. Apparently however the significance of this line does not stop here, for in ordinary ether there is a band coincident with this alcohol-band—in fact practically the visible spectrum produced by alcohol and ether are identical; but in all cases that we have seen the ether spectrum is clearer and sharper than the alcohol one. We thought it of importance to examining a sample of ether which should be as far as possible rendered pure by ordinary means, especially that it should be free from all traces of moisture: this sample gave a band precisely similar to the band in the ordinary commercial ether. Another sample of ether was saturated with water: in this case the ether band was as marked as ever, but the water-band was not visible.

We have also examined two other bodies which belong to the ethylic series, namely, aldehyde and acetic acid. Both give bands, but they are not so clear or definite as the alcohol or ether bands. Figs. 8 and 9 show these bands. The aldehyde band commences sharply at 628, but on the other side it shades gradually off and ceases at 620. The band in acetic acid is very faint, in fact at first, when using the 6-feet tube, we were led to think there was no visible band.

We also tried a few of the saline ethers, and, as far as our investigations have gone, the ethyl compounds give a band coincident with the alcohol- and ether-band. And the band of the amyl compounds is coincident with that of amylic alcohol. There appears, however, to be this general difference between the bands in the alcohols and those in the corresponding saline ethers, namely, that in the latter the bands are always broader and less distinct; the saline ethers we have examined are ethyl oxalate, amyl acetate, amyl iodide, and amyl nitrate.

Passing now to the aromatic series, we find that they give very marked absorption bands. Fig. 9 represents the bands given by benzene; the spectrum is remarkably

sharp and clear, quite as clear as the ether spectrum; the figure is drawn from the spectrum produced by 8 feet of the liquid. The absorption extends as far as 656; the first band is from 707 to 698, the second from 609 to 605; both are very dark and distinct. The third band extends from 531 to 528, and is very much fainter.

Toluene, the next higher member of this series, gave also a similar spectrum, and it is equally sharp (Fig. 10). As in the case of the alcohols, with increase of density the bands have moved nearer the red. It will be seen that the band in the red differs in position from the corresponding benzene band more than either of the other two bands do.

Cresol, unfortunately at present, we have not been able to examine for want of a sufficient quantity of the pure substance.

Phenol gives a spectrum very similar to the benzene spectrum; possibly the band about 610 is somewhat nearer the blue, but beyond this we could see no difference. In the first instance we tried melting the phenol, but afterwards found it far preferable to keep it liquid by the presence of a mere trace of water.

We looked with much interest to the two following experiments, with bodies of this series, namely, aniline and toluidene, to see how far their constitution might be indicated by their spectrum. Figs. 11 and 12 give respectively the spectra of these bodies. There is a band in the red in the same position as the toluene band, and in the case of aniline a band agreeing in part with the 606 benzene band. With toluidene, however, this band was not visible, but probably this arose from its being hidden by general absorption, the liquid used being slightly coloured. However, besides these two bands, both of these amido compounds gave a very clear band from 656 to 645, and it is certainly not without interest that this is coincident with one of the bands given by ammonia; whether any other band coincidences occur between these bodies we cannot say, as in both cases there was sufficient general absorption to hide them even if present.

Among other liquids we have tried turpentine, which appears to give a definite spectrum. This is shown at Fig. 13. With a thickness of 8 feet of carbon disulphide and a similar thickness of carbon tetrachloride, we could see no bands. However, with the former liquid it may prove that there is a band in the green, but as far as we could tell this is doubtful. One other experiment, which has some interest, is that the benzene spectrum is unaltered when the liquid is saturated with sulphur.

Such are the principal observations which we have made up to the present time. As stated at first, we look upon these results as preliminary, and as having to be repeated with more accurate means. Of course we have only dealt with the bands visible under ordinary conditions; still, the above results, as far as they go, have been made with much care, and we think show that most interesting relations exist between the chemical composition and constitution of a body and its absorption spectrum. Obviously a far more extended series of observations must be made before any general conclusions of value can be deduced.

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CELLULOID

THE product of the action of strong nitric acid upon cellulose has of late years met with many applications in the arts.

When cotton wool, linen, paper, or other substance largely consisting of cellulose, is immersed in strong nitric acid, a mixture of two or more nitro-celluloses is produced; a solution of this mixture in alcohol and ether has been long known as collodion.

About three or four years ago it was shown that this